Association of metals (Cd, Fe, As, Ni, Cu, Zn and Mn) with cigarette butts in northern part of the Persian Gulf

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ABSTRACT

Cigarette butts are the most common form of litter in the marine environment and represent potential point sources for environmental contamination. The metals leached from cigarette butts have not been studied well in the marine environment. In this study, the levels of metals (Cd, Fe, As, Ni, Cu, Zn and Mn) in cigarette butts were monitored at nine stations along the northern part of the Persian Gulf in Bushehr coastal areas in summer 2015 with a sampling time interval of 10 days. The Cd, Fe, As, Ni, Cu, Zn and Mn contents of cigarette butts were found to vary widely between 0.16 and 0.67 µg/g, 79.01 and 244.97 µg/g, 0.12 and 0.48 µg/g, 1.13 and 3.27 µg/g, 4.29 and 12.29 µg/g, 6.39 and 21.17 µg/g, and 38.29 and 123.1 µg/g, respectively. A Wilcoxon signed rank test showed that there were no significant differences between the Cd, Fe, As, Ni, Cu, Zn and Mn contents of cigarette butts at different sampling times. Considering the estimated number of cigarette butts littered annually, the results of this study indicated that considerable metals including Cd, Fe, As, Ni, Cu, Zn and Mn may enter the marine environment each year from cigarette litter alone.

INTRODUCTION

Cigarette butts have been found to be a major source of shoreline accumulation of macroplastic debris.[1] There are many reports in the field of plastic and microplastic debris, especially from the USA, Western Europe, Oceania and East Asia, but there is no report in the region of the Persian Gulf.[2] To the best of our knowledge, there is no published literature on the extent of cigarette butts with metals in marine environments. Heavy metals with high bioaccumulation capability are persistent and abundant contaminants, and most likely exist at high content levels in the marine environment and biota samples. Since it is most likely that cigarette butts serve as a means of transporting metals in the marine environment, in the present study we aimed to determine the levels of Cd, Fe, As, Ni, Cu, Zn and Mn in cigarette butts along the northern part of the Persian Gulf in the Bushehr seaport coastal areas.

MATERIALS AND METHODS

Study area and sampling

To investigate the levels of Cd, Fe, As, Ni, Cu, Zn and Mn in cigarette butts, field surveys were conducted at nine stations (S_1–S_9) along the northern part of the Persian Gulf in Bushehr coastal areas (online supplementary appendix 1) in summer 2015. All stations are close to urban areas. At each beach studied (S_1–S_9), sediment samples from the top 10 cm were collected at the tidal mark on the beach from a 1 m^2 area; the collected sediment was transferred to the laboratory. Sampling at each beach studied was performed two times with a time interval of 10 days to evaluate the marine current effects on metal concentration in cigarette butts.

Reagent

The employed reagents were of analytical grade. HNO_3 and HCl used for the extraction procedure were of supra pure quality (Merck, Darmstadt, Germany). All plastic and glassware were cleaned by soaking overnight in a 10% (w/v) HNO_3 solution and then rinsed with deionised water before use. Solutions were prepared by using ultrapure water (18.2 µΩ cm).

Metal analysis

Cigarette butts from every sampling station and sampling time were selected without considering the levels of adherent material. Adherent material was removed from the beached cigarette butts. Cd, Fe, As, Ni, Cu, Zn and Mn were extracted from cigarette butts using a modified aqua regia extraction. Aqua regia was prepared by mixing 3 MHNO_3 and 2 MHCl in a ratio of 1:3.[3] Weighed cigarette butts were added to polypropylene centrifuge tubes and 20 mL of aqua regia was added; then the tubes were shaken laterally at 100 rpm for 24 hours. The same bulk preparation of aqua regia was used throughout extraction for all blanks and calibration to ensure consistency in the analysis of extraction. The filtered samples were analysed for the contents of Cd, Fe, As, Ni, Cu, Zn and Mn using a graphite furnace atomic absorption spectrophotometer (Varian AA240, USA). The accuracy and precision of the method were determined. Recovery (%) ranged from 91 to 107%, and relative standard deviation (%) ranged from 0.8% to 5.9%. The limit of detection and limit of quantification for each examined element were calculated (online supplementary appendix 2). Statistical analysis was carried out with SPSS and the Wilcoxon signed rank test was performed to test for statistically significant differences. Differences in mean values were accepted as being significant if $p<0.05$.

RESULTS

The Cd, Fe, As, Ni, Cu, Zn and Mn contents of cigarette butts along the northern part of the Persian Gulf, as measured, are shown in table 1. The Cd, Fe, As, Ni, Cu, Zn and Mn contents were found to vary widely between 0.16 and 0.67 µg/g,

Table 1 Contents of Cd, Fe, As, Ni, Cu, Zn and Mn (μg/g) in cigarette butts (maximum values are expressed as bold italics; minimum values as bold underlined)

Metal	Stations Sampling interval time	TV park (S_1)	Jofreh park (S_2)	Shoghab Park (S_3)	Rishehr park (S_4)	Lian park (S_5)	Bandargah harbour (S_6)	Negin island (S_7)	Abassak island (S_8)	Shif island (S_9)	Mean
Cd	First day	0.32	0.52	***0.54***	0.29	0.36	0.53	0.44	**0.16**	0.32	**0.38±0.12**
	After 10 days	0.44	0.36	**0.21**	0.31	***0.67***	0.37	0.3	0.29	**0.21**	**0.35±0.14**
Fe	First day	93.9	112.68	139.68	**79.01**	***193.3***	151.25	146.2	139.3	114.9	**130±34**
	After 10 days	158.5	193.8	111.77	151.29	215.8	**99.33**	***244.97***	170.7	154.8	**166.8±46**
As	First day	0.24	**0.13**	0.47	0.2	0.21	0.17	***0.48***	0.15	0.27	**0.25±0.13**
	After 10 days	0.19	0.18	0.15	**0.12**	0.19	0.27	0.16	***0.47***	0.2	**0.21±0.1**
Ni	First day	**1.79**	2.01	1.94	2.39	2.51	2.31	***3.27***	2.51	2.17	**2.3±0.43**
	After 10 days	***2.76***	1.84	1.71	1.89	1.69	**1.13**	2.65	1.58	1.63	**1.87±0.51**
Cu	First day	7.86	***12.29***	5.04	5.13	**4.29**	4.5	8.4	5.05	7.58	**6.68±2.61**
	After 10 days	6.08	7.37	4.78	4.88	9.25	5.01	**4.39**	***10.91***	9.56	**6.91±2.44**
Zn	First day	17.24	15.67	**7.55**	16.56	10.38	14.33	***21.17***	16.38	16.89	**15.31±4**
	After 10 days	13.37	9.64	13.95	12.44	***17.4***	**6.39**	15.08	8.96	13.93	**12.35±3.4**
Mn	First day	50.77	***117.56***	79.56	**38.29**	88	103.14	49.55	107.19	95.12	**80.95±28**
	After 10 days	**75.89**	80.61	114.71	71.93	***123.1***	70.59	79.75	119.33	74.68	**90.06±22**

79.01 and 244.97 μg/g, 0.12 and 0.48 μg/g, 1.13 and 3.27 μg/g, 4.29 and 12.29 μg/g, 6.39 and 21.17 μg/g, and 38.29 and 123.1 μg/g, respectively. There were no significant differences between the Cd, Fe, As, Ni, Cu, Zn and Mn contents at different sampling times along the urban coastal area. The mean values of the Cd, Fe, As, Ni, Cu, Zn and Mn contents were 0.38±0.12 and 0.35 ±0.14 μg/g, 130±34 and 166.8±16 μg/g, 0.25±0.13 and 0.21 ±0.1 μg/g, 2.3±0.43 and 1.87±0.51 μg/g, 6.68±2.61 and 6.91 ±2.44 μg/g, 15.13±4 and 12.35±3.41 μg/g, and 80.95±28 and 90.06±22 μg/g at the first day and after 10 days, respectively.

DISCUSSION

The metals leached from cigarette butts have been identified and quantified by only a few studies and these studies were not in marine environments. Ashton *et al*[3] measured the association of metals (Al, Fe, Mn, Cu, Zn, Pb, Ag, Cd, Co, Cr, Mo, Sb, Sn, U) with plastic production pellets in the marine environment. They suggested that micro and macro plastic fragments accumulate and transport metals in the marine environment and can be used as metal contamination indicators. Metals on plastic pellets are adsorbed to the surface of plastic pellets or associated with biogenic or hydrogeneous phases, and can occur in a relatively bioaccessible form to fauna that accidentally ingest them.[3] In a recent study examining the interactions between trace metals and plastic production pellets under estuarine conditions, it was observed that adsorption of all examined metals including Cd, Co, Cr, Cu, Ni and Pb was higher for beached pellets than for virgin pellets.[4] In another study, Holmes *et al*[5] studied adsorption of trace metals (Cr, Co, Ni, Cu, Zn, Cd and Pb) to plastic resin pellets in the marine environment and concluded that plastics may represent a main vehicle for metals transport in the marine environment.

Cigarette filters—made of cellulose acetate—may behave like other plastics in transporting metals in the marine environments. The occurrence of different metals in cigarettes can mainly be attributed to cultivation and growth of tobacco.[6] Insecticide, herbicides and pesticide application may also introduce metals to the tobacco leaf.[7] Further introduction of metals may occur during cigarette manufacture,[8 9] or during application of brightening agents on the wrapping paper.[10–12] The response of biota to the metal content level is extremely different.[13 14] Whereas elevated concentration of heavy and trace metals in water and soils can adversely affect some species, contamination may increase the metal tolerance of other organisms (eg, bioaccumulators). Slaughter *et al* showed that toxicity of cigarette butt leachate increased from unsmoked cigarette filters (no tobacco) to smoked cigarette filters (no tobacco) to smoked cigarette butts (smoked filter+tobacco). They affirmed the toxicity of cigarette butts to fish and some other representative marine organisms such as daphnids and marine bacteria.[15] Moreover, other studies have also shown that heavy metals and chemicals in cigarette butt leachate may be acutely toxic to marine species.[16–18] So, considering the estimated amount of cigarette butts littered annually (4.95 trillion),[19] the release of metals from littered cigarette butts in the marine environment may increase the potential for acute harm to local species and may enter the food chain.

CONCLUSION

In this study, the levels of Cd, Fe, As, Ni, Cu, Zn and Mn in cigarette butts along the northern part of the Persian Gulf were determined. The results of our study indicate that considerable metals including Cd, Fe, As, Ni, Cu, Zn and Mn may enter the marine environment and coastline area each year from cigarette litter alone.

More research is necessary to fully understand the leaching behaviour of metals from cigarette butts in the marine environment. Enhanced public awareness about the toxicity of discarded cigarette butts in the marine and coastline areas may help to decrease the environmental hazards of cigarette butts in these areas.

What this paper adds

- There are some reports that showed metals leached from cigarette butts, but these studies were not in the marine environment. A few studies reported the levels of metal in plastic production pellets in the marine environment but not in cigarette butts.
- This study presents primary data on the levels of metals in cigarette butts in a marine environment. We found measurable levels of Cd, Fe, As, Ni, Cu, Zn and Mn in cigarette butts along the northern part of the Persian Gulf. Cigarette butts may serve as a means for transport of metals in the marine environment and notable metals may enter the coastline areas by cigarette litter annually.

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Contributors SD designed and wrote the manuscript and also supervised all steps of the study. IN and RS guided in design of experiments and manuscript preparation. AO analysed the data. MK, NK, RH and MK collected the samples and conducted the experiments.

Competing interests None declared.

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